

Off-angle Thermal Spray Coating Deposition: Enabling Approach to Coat Small Internal Diameters

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Technology need

- **What technology is being used currently?**

- Hard Cr plating (wear, corrosion prevention, improved lubricity in presence of lubricant)

- **Why do we need alternative technology?**

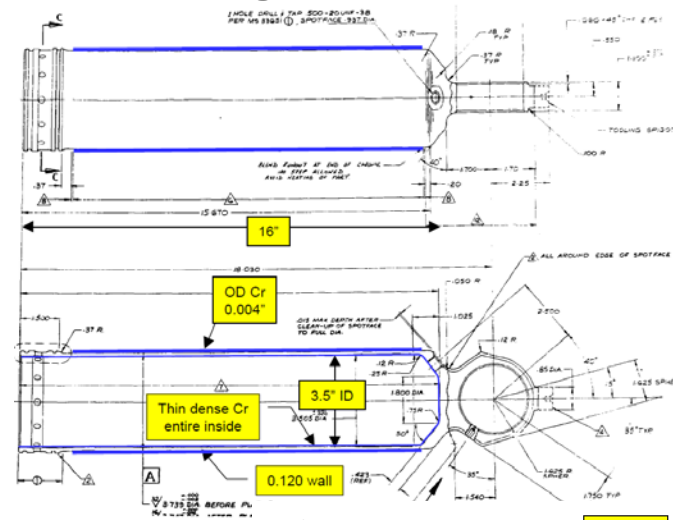
- Environmental/regulation problems – Hexavalent Cr is highly carcinogenic and is regulated
- Thermal spray coating has longer service life
- Cr plating getting more and more costly
- Cr plating is very slow process
- We are moving to future light weight

- **An example application**

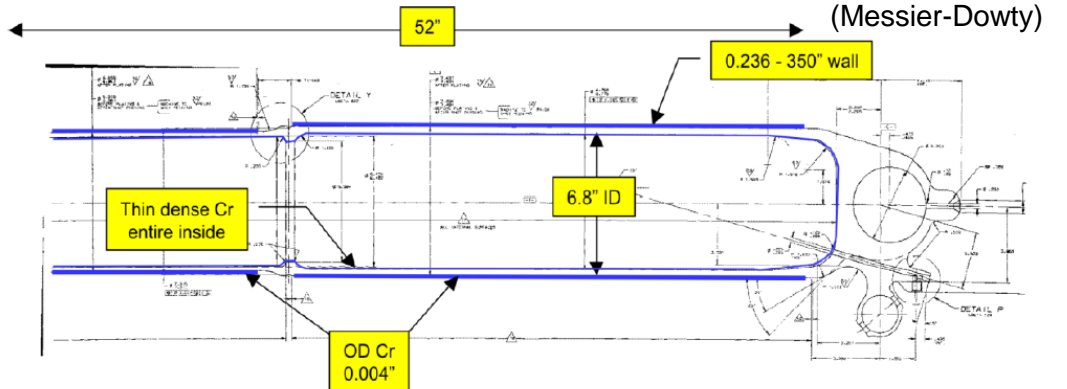
- Landing gear internal diameters
 - Down to 1" up to 7"
 - WC-CoCr and CrC-NiCr as coating materials

What we are trying to do?

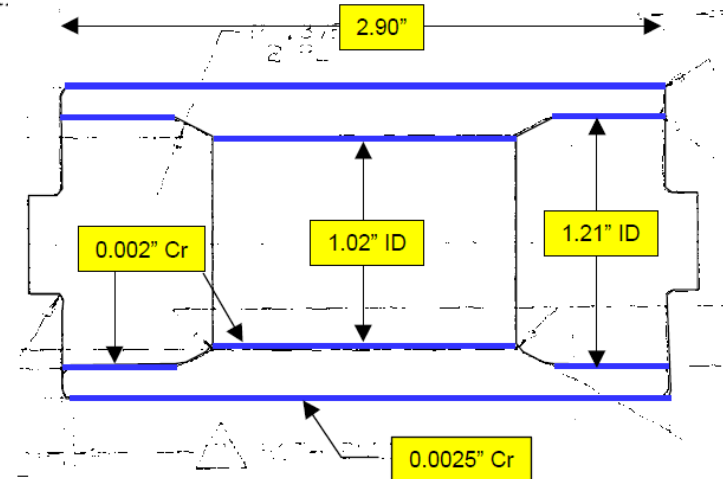
- Replacing the hard Cr plating in non-line of sight components employing thermal spray technique



Landing gear actuator cylinder – (Messier-Dowty)

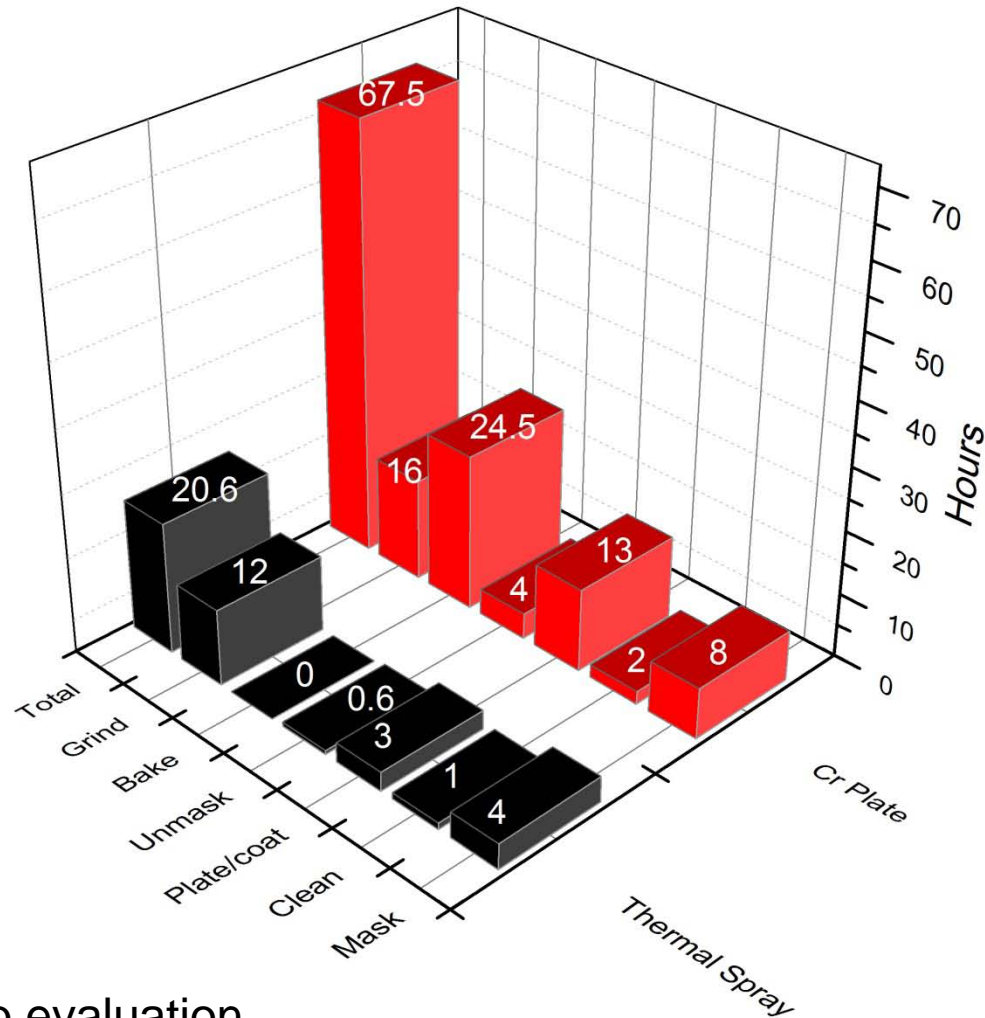


Landing gear actuator cylinder – (Messier-Dowty)



MLG shock strut piston (Messier-Dowty)

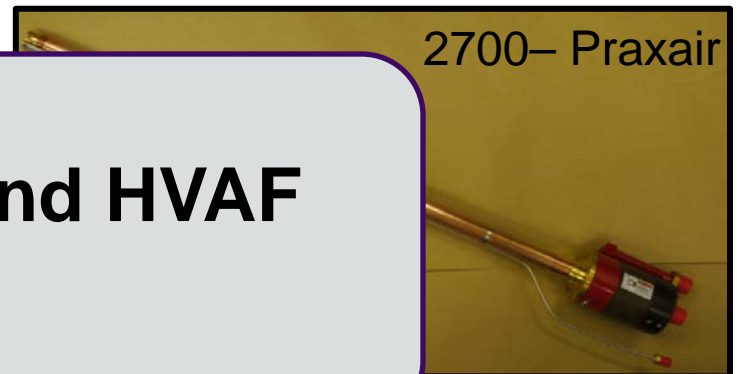
Cr plating Vs. thermal spray



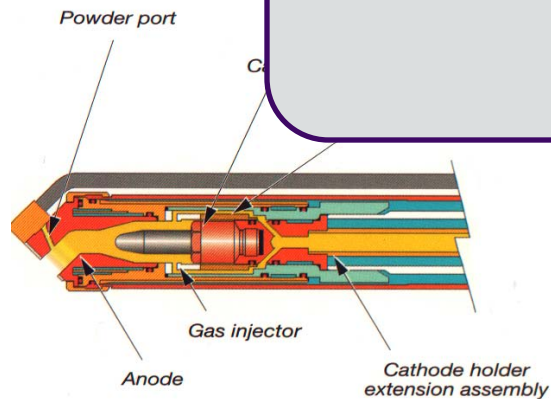
Ref: Sulzer Metco evaluation

Solution#1: Internal diameter plasma torches (minimum 3.5" IDs)

External feeding



What about HVOF and HVAF systems?



Solution #2: Off angle HVOF spraying (less than 3.5" IDs)

Cross section of ID component



Effect of different spray angles on:

Microstructure

Stresses

Mechanical properties

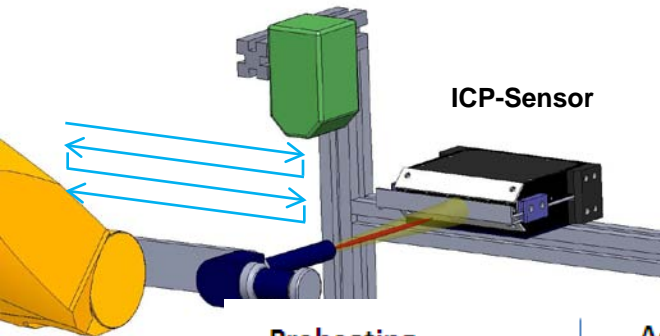
Performance

Off angle

Normal spraying



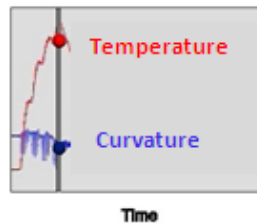
Coating formation – Understanding the stress formation



-Curvature is monitored by lasers at three points while temperature is measured by contact thermocouples.

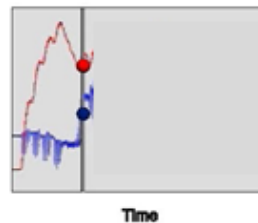
Preheating:

Uncoated substrate, stress relief (from grit blasting) due to heating.



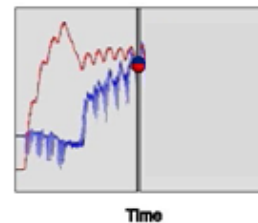
Adhesion Pass:

First pass, initial bending, better adhesion, coating pulls harder, retains more stress.



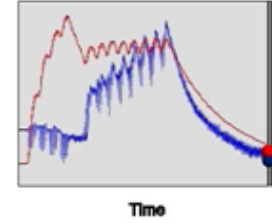
Evolving Stress:

Each layer shows similar residual stress, check consistency, cohesion and peening

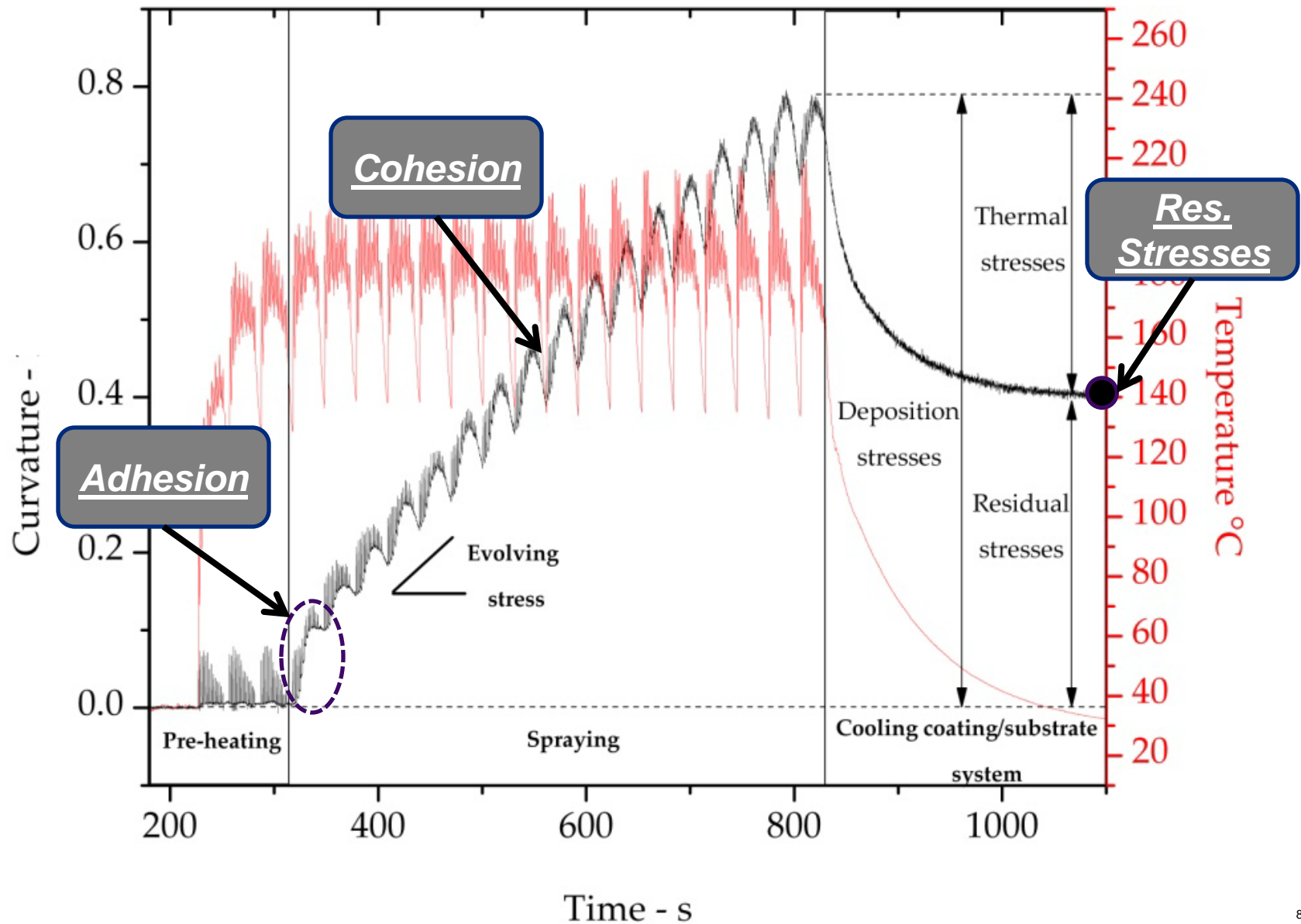


Cooling Curve:

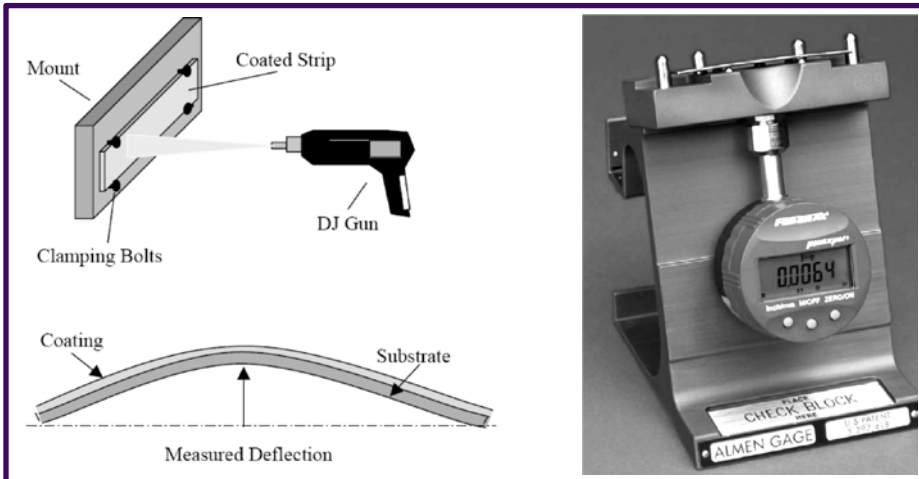
Coating elastic modulus, non-linearity, stress-strain curve, and residual stress can be extracted.



Interpretation of ICP data



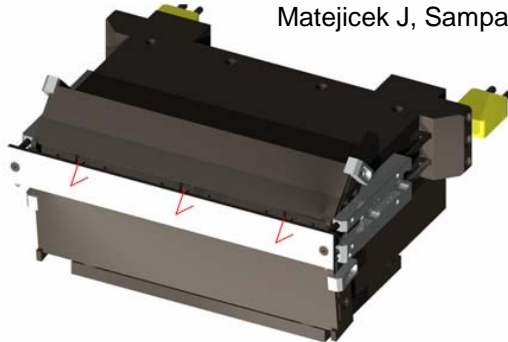
Almen Vs. ICP



<u>Standard</u>	Equi. Stress [Mpa]
Spec I	-120 to -480
Spec II	-240 to -600

ICP Sensor

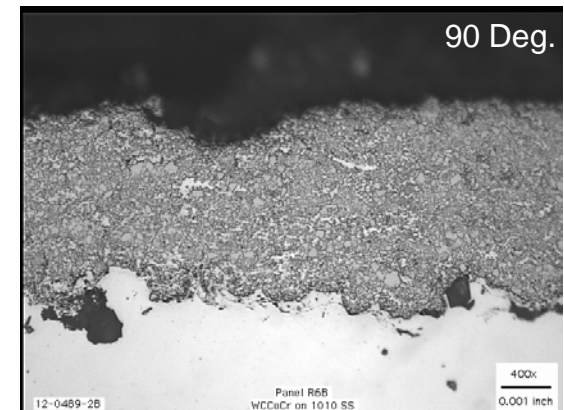
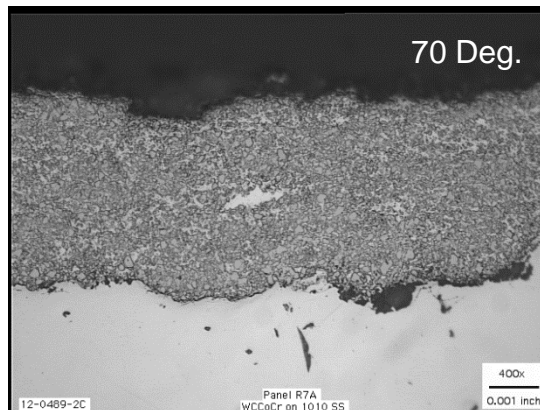
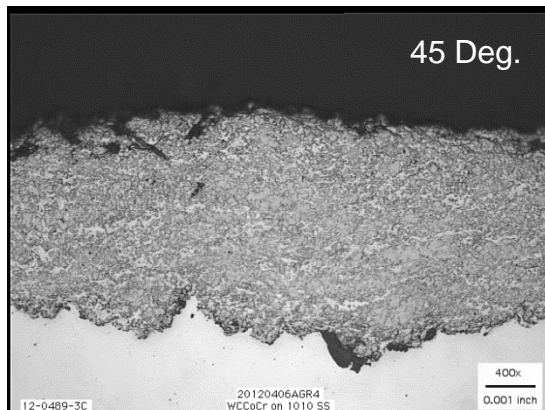
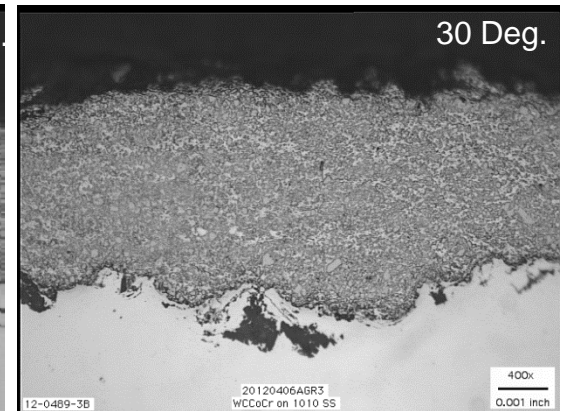
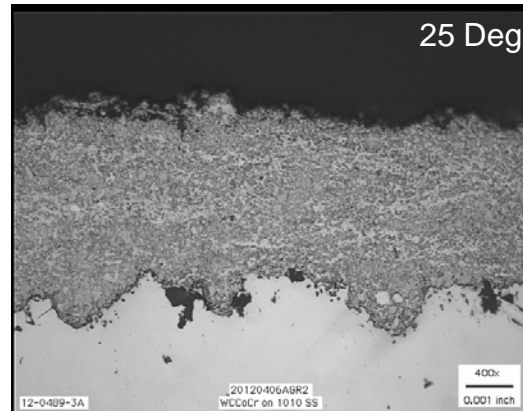
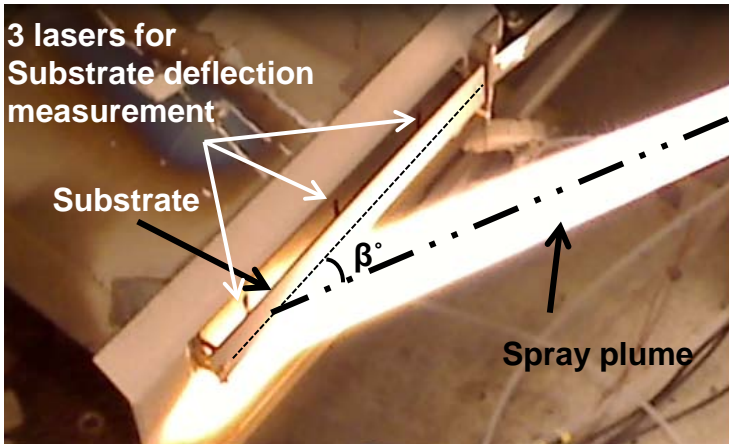
Matejcek J, Sampath S. US Patent 6,478,875.



- ❑ No Evolution of the Stresses,
- ❑ No temperature history
- ❑ Non uniform stress distribution due to restraining
- ❑ Limited information to design coatings
- ❑ Only applicable to steel substrates
- ❑ Variables under no-control:
 - ❖ substrate temperature,
 - ❖ peening from grit-blasting,
 - ❖ holder type
 - ❖ deposition rates

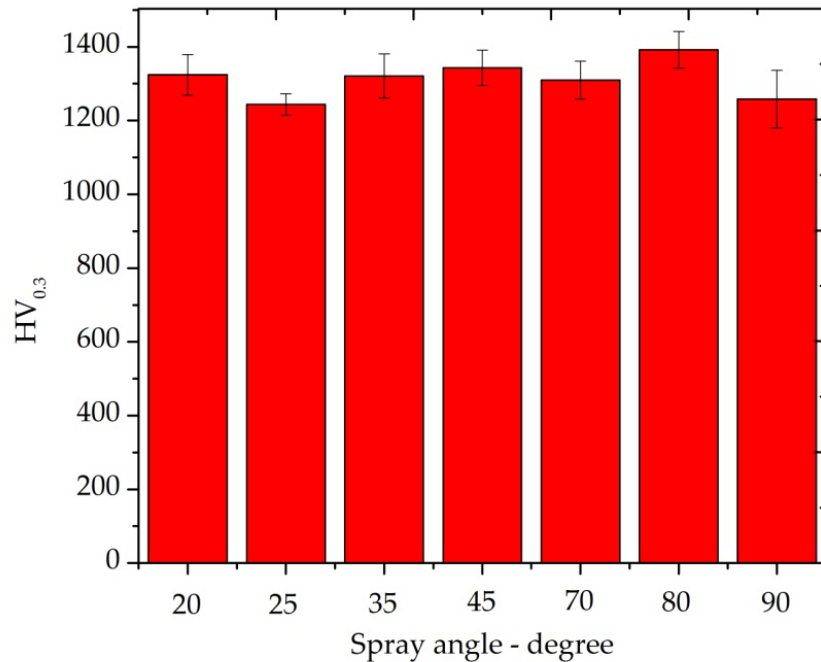
- ❑ Develops detail understanding of evolving of stress,
- ❑ Provides temperature history
- ❑ Uniform stress distribution
- ❑ Provides through thickness stresses within coating and substrate useful for coating design
- ❑ No limitation on substrates
- ❑ Can help to develop in depth understanding of following parameters on stresses:
 - ❖ substrate temperature,
 - ❖ Process variables,
 - ❖ Deposition rates

Off angle spraying: Enabling approach



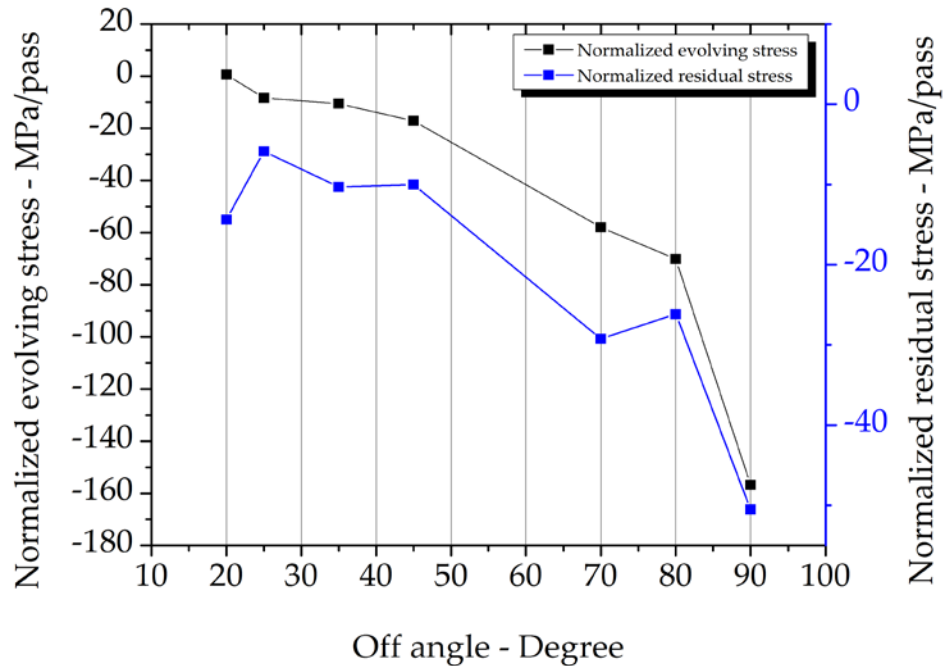
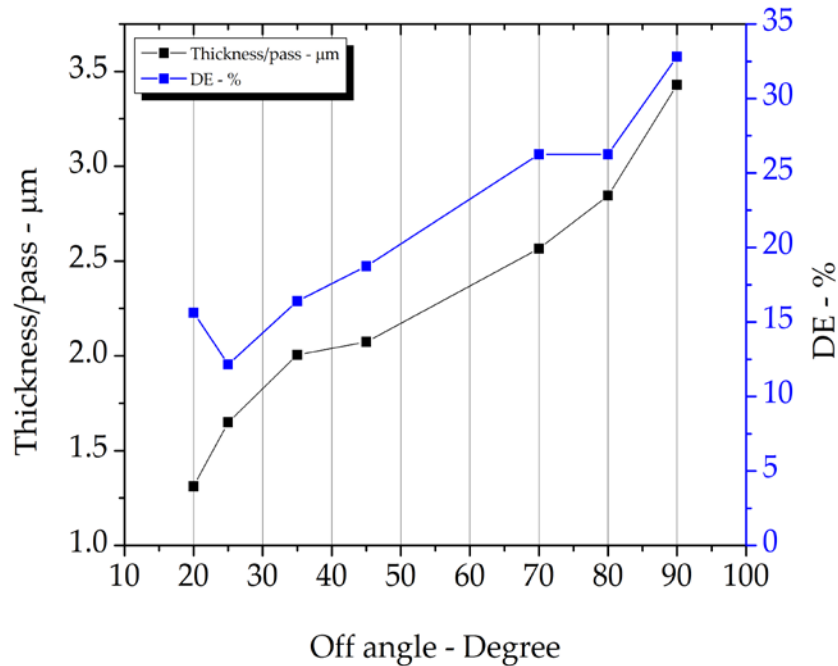
Spraying angle has no impact on the microstructure of coating.
Obtaining microstructure from different orientation is required.

Off angle spraying: Enabling approach



Spray angle has no impact on the measured coating hardness.
Obtaining microstructure from different orientation is required.

Off angle spraying: Enabling approach



Off angle spraying: Enabling approach

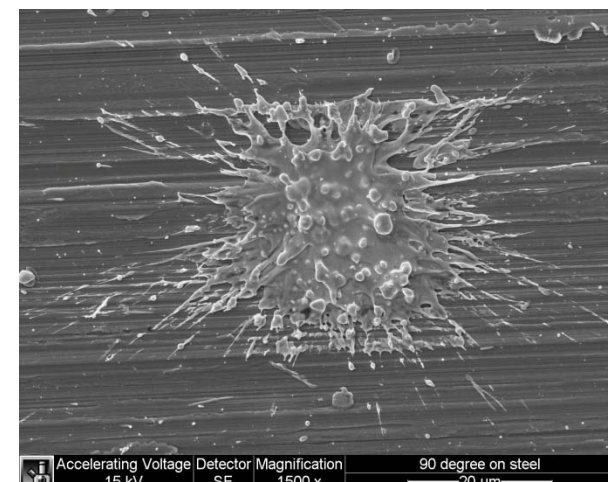
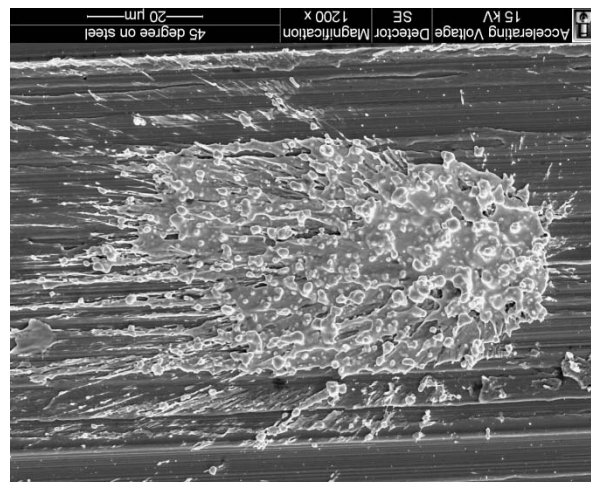
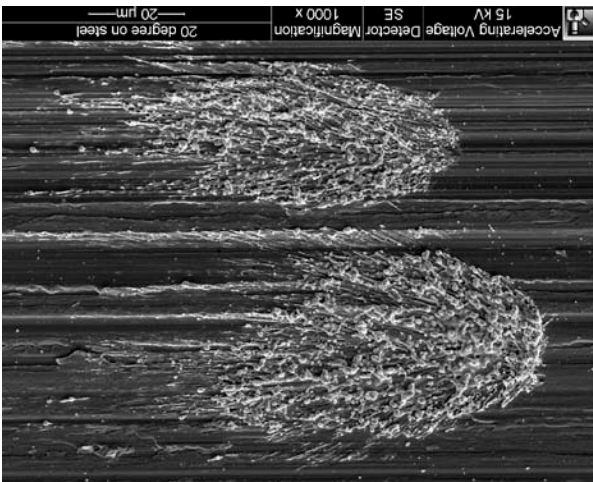
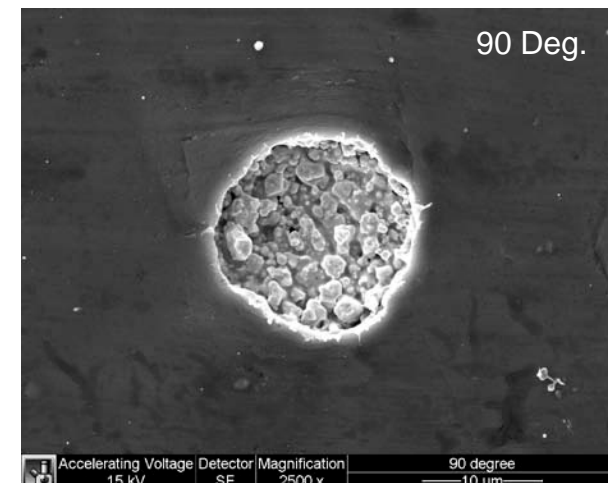
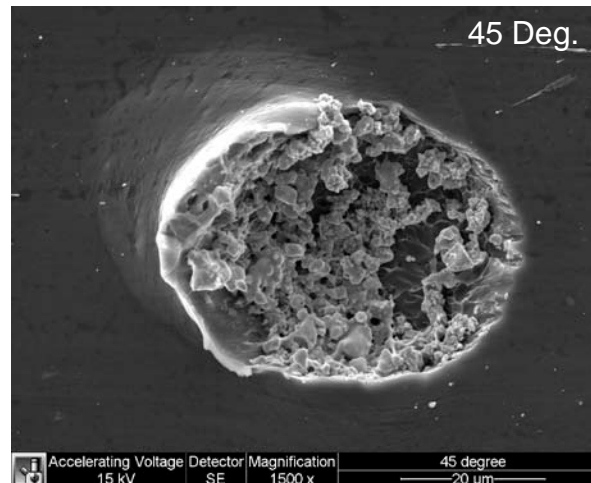
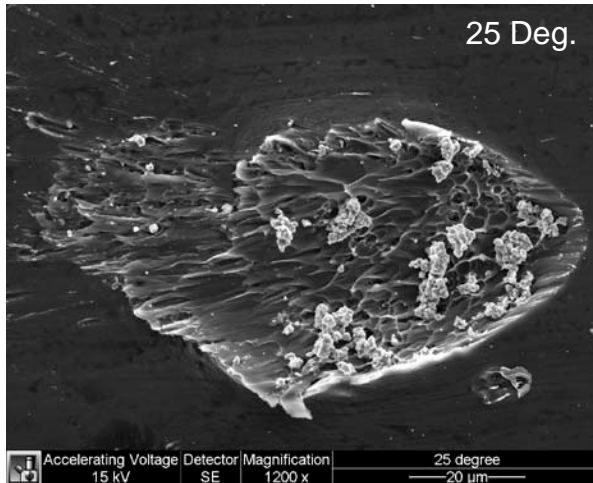
Increase in DE & peening



25 Deg.

45 Deg.

90 Deg.



Conclusion

- **Coating stresses are highly sensitive to spray angle.**
- **Microstructure and hardness are not significantly affected by spray angle.**
- **It is hypothesized that spray angle increases the anisotropy of TS coating and further studies addressing the issues related to anisotropy is required.**